



US009458929B2

(12) **United States Patent**
Maurer et al.

(10) **Patent No.:** **US 9,458,929 B2**
(45) **Date of Patent:** **Oct. 4, 2016**

(54) **METHOD FOR OPERATING AN
AUTOMATIC TRANSMISSION**

USPC 475/303; 701/64
See application file for complete search history.

(71) Applicant: **ZF Friedrichshafen AG**,
Friedrichshafen (DE)

(56) **References Cited**

(72) Inventors: **Markus Maurer**, Lindau (DE);
Martina Jehle, Eriskirch (DE); **Ruben
Cueppers**, Wangen (DE); **Max
Trautwein**, Kressbronn (DE)

U.S. PATENT DOCUMENTS

8,398,522	B2	3/2013	Bauknecht et al.	
8,812,200	B2	8/2014	Novak	
9,228,656	B1 *	1/2016	Schmidt	F16H 61/0403
2011/0263382	A1 *	10/2011	Arnold	F16H 61/0403 477/121
2012/0283064	A1 *	11/2012	Herbeth	F16H 61/04 475/275
2016/0102753	A1 *	4/2016	Schmidt	F16H 61/0403 701/51
2016/0102756	A1 *	4/2016	Schmidt	F16H 61/0403 701/51

(73) Assignee: **ZF FRIEDRICHSHAFEN AG**,
Friedrichshafen (DE)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **14/639,235**

DE	102009000253	1/2009
WO	WO 2010081819	7/2010

(22) Filed: **Mar. 5, 2015**

* cited by examiner

(65) **Prior Publication Data**

US 2016/0258530 A1 Sep. 8, 2016

Primary Examiner — Roger Pang

(74) *Attorney, Agent, or Firm* — Dority & Manning, P.A.

(51) **Int. Cl.**

F16H 61/04 (2006.01)

F16H 61/06 (2006.01)

(57) **ABSTRACT**

(52) **U.S. Cl.**

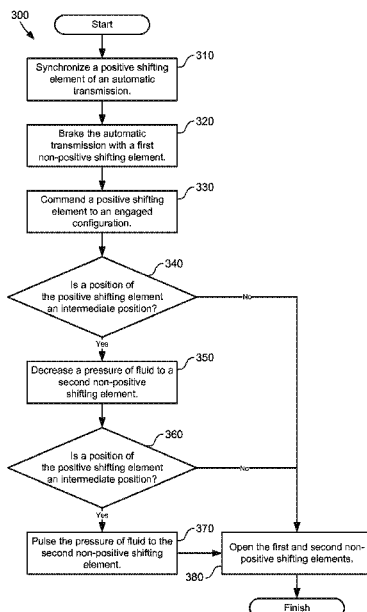
CPC **F16H 61/0403** (2013.01); **F16H 61/0437**
(2013.01); **F16H 61/061** (2013.01); **F16H**
2061/047 (2013.01); **F16H 2061/0474**
(2013.01); **Y10T 477/675** (2015.01); **Y10T**
477/68 (2015.01)

A method for operating an automatic transmission is provided. The method includes synchronizing a positive shifting element of the automatic transmission, braking the automatic transmission with a first non-positive shifting element, establishing a position of the positive shifting element, and increasing a pressure of fluid supplied to a second non-positive shifting element if the position of the positive shifting element is an intermediate position.

(58) **Field of Classification Search**

CPC . **Y10T 477/675**; **Y10T 477/68**; **F16H 61/04**;
F16H 2061/0474; **F16H 2061/047**; **F16H**
61/0403; **F16H 61/0437**; **F16H 61/061**

20 Claims, 4 Drawing Sheets



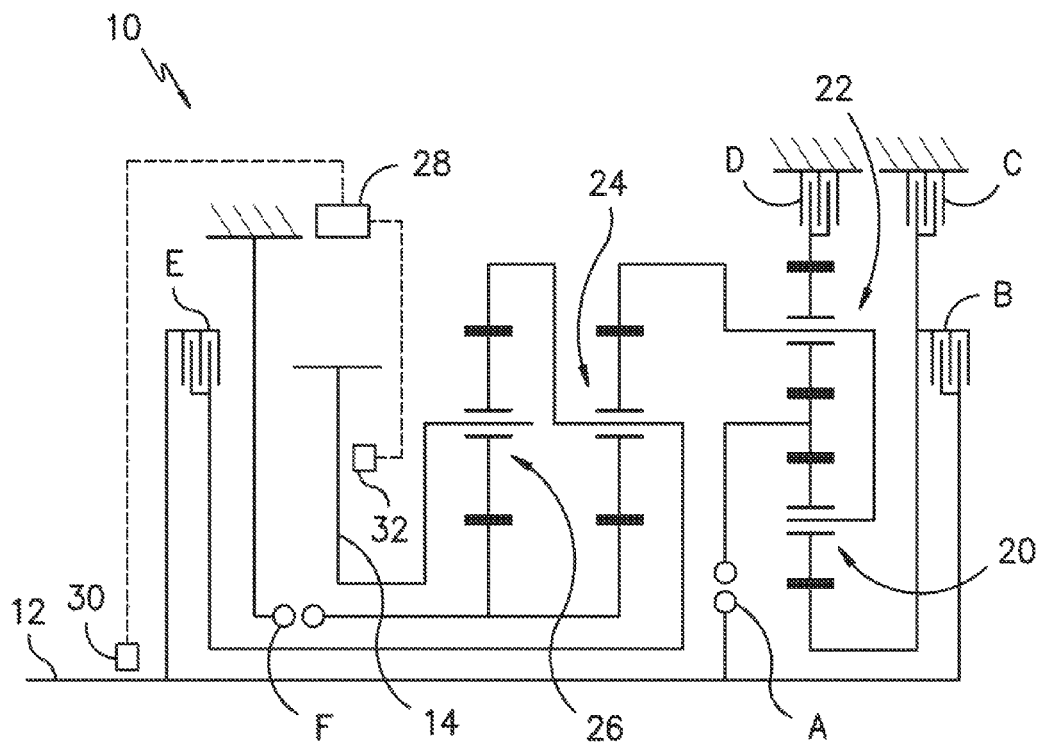
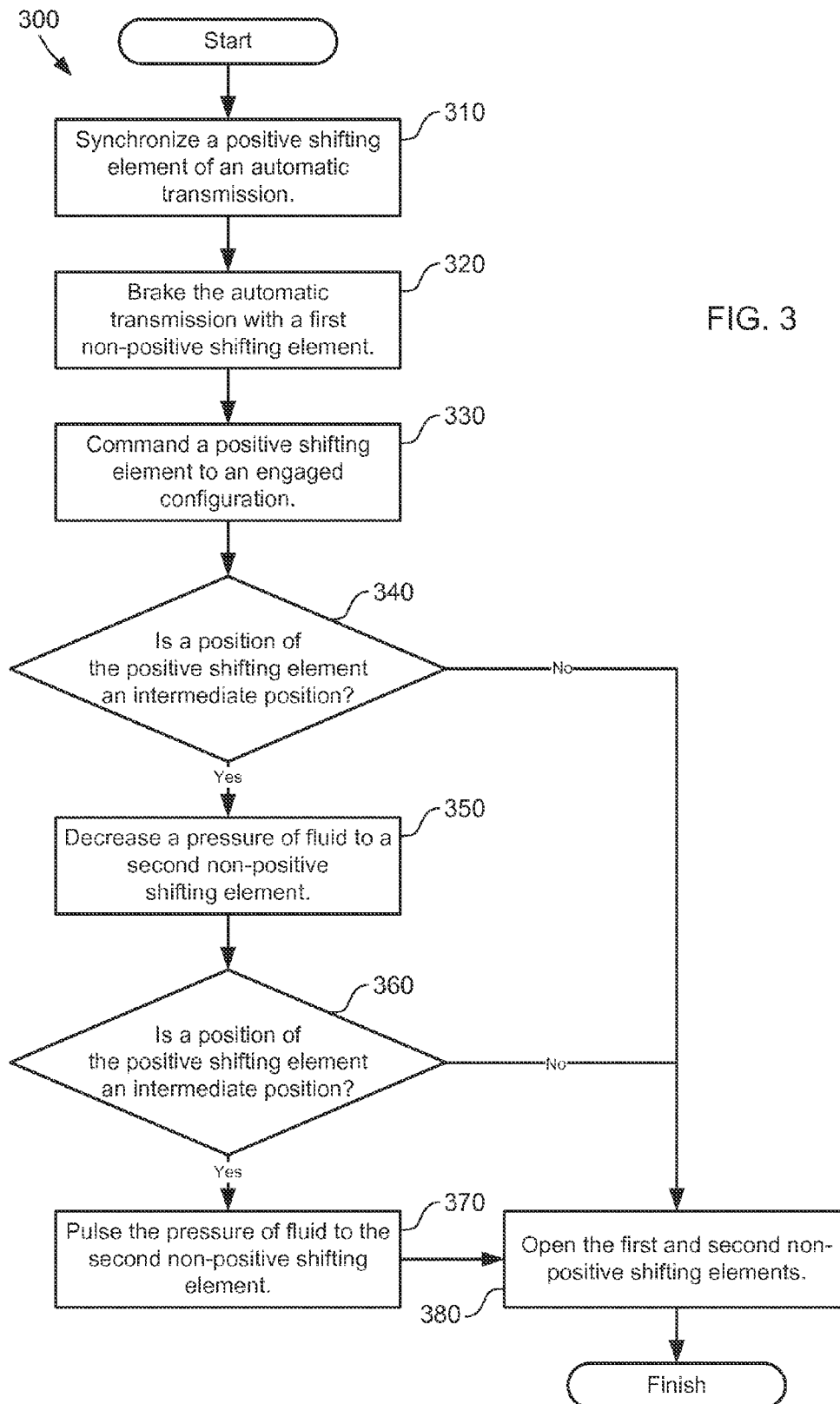


FIG. 1



	A	B	C	D	E	F
"1"	X			X		X
"2"	X		X			X
"3"	X	X				X
"4"	X				X	X
"5"	X	X			X	
"6"	X		X		X	
"7"	X			X	X	
"8"			X	X	X	
"9"		X		X	X	
"R"		X		X		X

FIG. 2



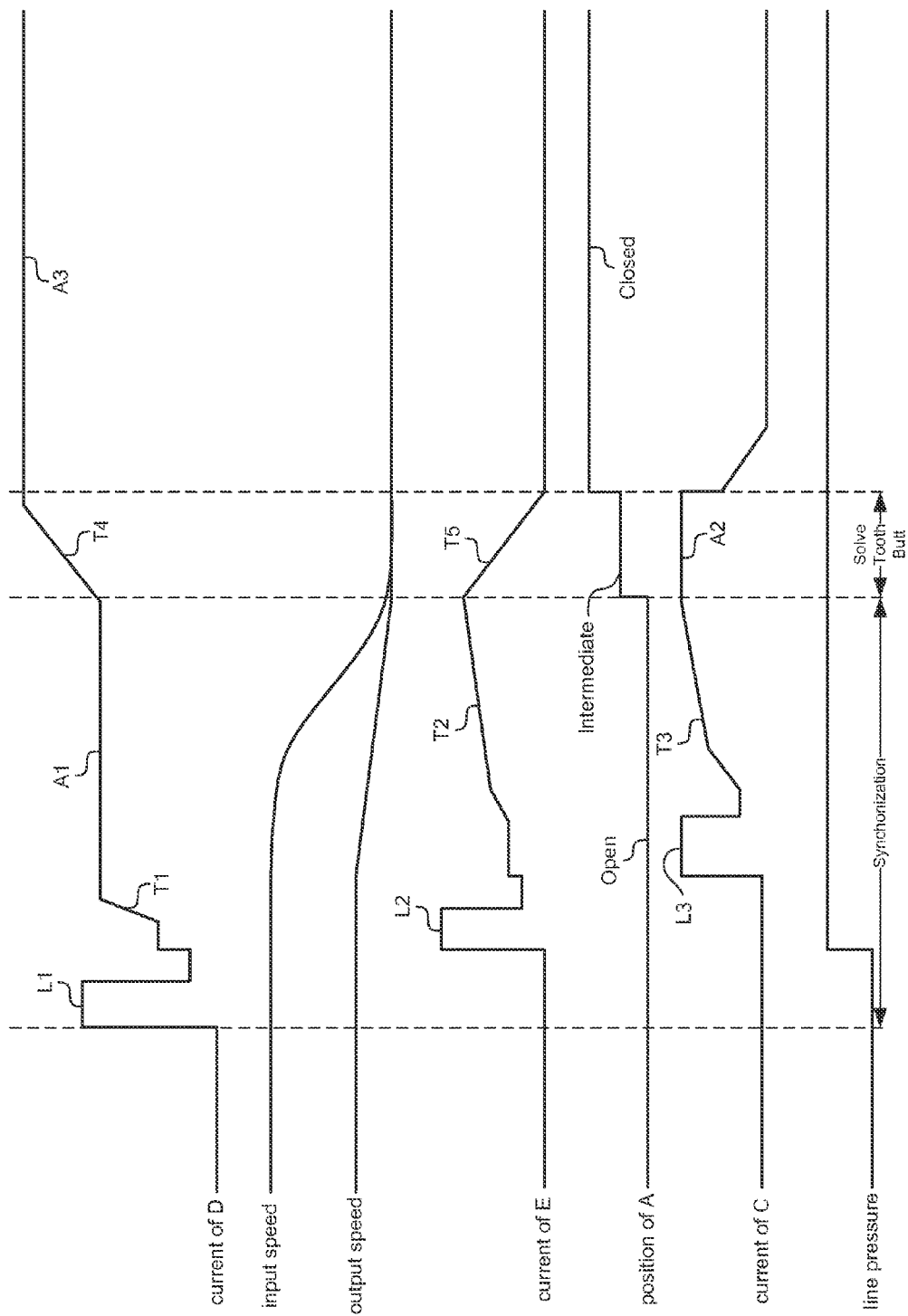


FIG. 4

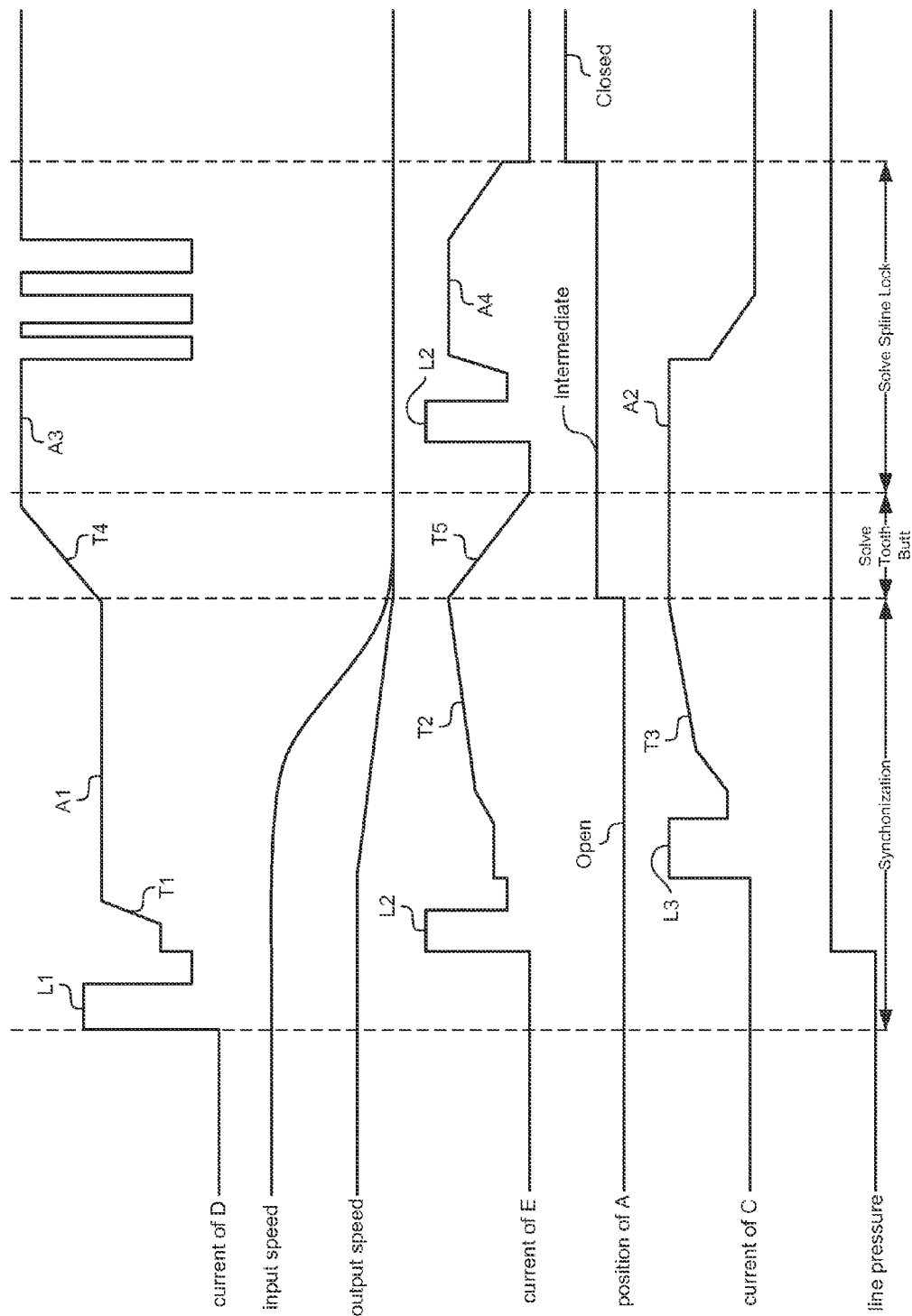


FIG. 5

1

METHOD FOR OPERATING AN AUTOMATIC TRANSMISSION

FIELD OF THE INVENTION

The present subject matter relates generally to automatic transmissions, such as nine-speed automatic transmissions.

BACKGROUND OF THE INVENTION

Automatic transmissions generally include at least one planetary gear set and a plurality of shift elements. The shift elements selectively engage components of the planetary gear sets in order to hinder or prevent rotation of the components. Selective actuation of the shift elements adjusts the gear ratio of the automatic transmission and shifts the automatic transmission between its various gears.

Certain automatic transmissions include dog clutch shifting elements. During various gear shifts, the dog clutch is engaged or closed. Engaging the dog poses certain challenges. For example, the dog clutch is generally synchronized prior to engaging the dog clutch. When the dog clutch is synchronized, components of the dog clutch rotate at a common speed and may engage each other more easily. Conversely, such components may grind against each other and be damaged if the dog clutch is engaged while the dog clutch is not synchronized. However, synchronizing the dog clutch can be difficult and/or time consuming. For example, a separate synchronizing mechanism can consume valuable space within a transmission and add to an overall cost of the automatic transmission.

Certain conditions can also hinder or prevent actuation of the dog clutch. For example, even when the dog clutch is synchronized, teeth of the dog clutch can butt against one another and hinder or prevent engagement of the dog clutch. As another example, the teeth of the dog clutch can stick and hinder or prevent actuation of the dog clutch even when the dog clutch is synchronized.

Accordingly, a method for synchronizing a dog clutch of an automatic transmission would be useful. In particular, a method for synchronizing a dog clutch of an automatic transmission that also includes steps for ameliorating tooth butting and/or spline locking of the dog clutch would be useful.

BRIEF DESCRIPTION OF THE INVENTION

The present subject matter provides a method for operating an automatic transmission. The method includes synchronizing a positive shifting element of the automatic transmission, braking the automatic transmission with a first non-positive shifting element of the automatic transmission, establishing a position of the positive shifting element, and increasing a pressure of fluid supplied to a second non-positive shifting element of the automatic transmission if the position of the positive shifting element is an intermediate position. Additional aspects and advantages of the invention will be set forth in part in the following description, or may be apparent from the description, or may be learned through practice of the invention.

In a first exemplary embodiment, a method for operating an automatic transmission is provided. The automatic transmission has a plurality of non-positive shifting elements and at least one positive shifting element. The method includes synchronizing a first positive shifting element of the at least one positive shifting element, braking the automatic transmission with a first non-positive shifting element of the

2

plurality of non-positive shifting elements, and commanding the first positive shifting element of the at least one positive shifting element to actuate from a disengaged configuration to an engaged configuration after the step of synchronizing.

A second non-positive shifting element and a third non-positive shifting element of the plurality of non-positive shifting elements are in the engaged configuration at the step of commanding. The method also includes establishing a position of the first positive shifting element of the at least one positive shifting element after the step of commanding and increasing a pressure of fluid supplied to the second non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is an intermediate position at the step of establishing.

In a second exemplary embodiment, a method for operating a nine-speed automatic transmission is provided. The nine-speed automatic transmission includes a dog clutch A, a friction shifting element C, a friction shifting element D, and a friction shifting element E. The method includes synchronizing the dog clutch A, braking the automatic transmission with the friction shifting element C, and commanding the dog clutch A to actuate from a disengaged configuration to an engaged configuration after the step of synchronizing. The friction shifting element D and the friction shifting element E are in the engaged configuration at the step of commanding. Establishing a position of the dog clutch A after the step of commanding and increasing a pressure of fluid supplied to the friction shifting element D if the position of the dog clutch A is an intermediate position at the step of establishing.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

FIG. 1 provides a schematic view of an automatic transmission according to an exemplary embodiment of the present subject matter.

FIG. 2 illustrates a table of an exemplary shifting scheme as may be used with the exemplary automatic transmission of FIG. 1.

FIG. 3 illustrates a method for operating an automatic transmission according to an exemplary embodiment of the present subject matter.

FIGS. 4 and 5 illustrate plots of shifting element actuation for the exemplary automatic transmission of FIG. 1 during the exemplary method of FIG. 3.

DETAILED DESCRIPTION

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit

of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

FIG. 1 provides a schematic view of an automatic transmission 10 according to an exemplary embodiment of the present subject matter. Automatic transmission 10 may be constructed or arranged in a similar manner to the automatic transmission described in U.S. Pat. No. 8,398,522 to Bauknecht et al., which is hereby incorporated by reference for all purposes. Automatic transmission 10 may be used in any suitable vehicle. For example, automatic transmission 10 may be used in a passenger vehicle, such as a car, truck or sport utility vehicle (SUV). Automatic transmission 10 is configured for selectively adjusting a gear ratio of automatic transmission 10, as will be understood by those skilled in the art, in order to provide a suitable mechanical advantage to propel the associated vehicle.

As may be seen in FIG. 1, automatic transmission 10 includes an input shaft 12 and an output shaft 14. Input shaft 12 may be coupled to a turbine of a torque converter in order to link automatic transmission 10 to a motor of an associated vehicle. Output shaft 14 may be coupled a front axle drive shaft of the associated vehicle. Automatic transmission 10 may change gears in order to adjust the gear ratio between the motor and front axle drive shaft of the associated vehicle, as will be understood by those skilled in the art.

Automatic transmission 10 also includes four planetary gear sets: a first planetary gear set 20; a second planetary gear set 22; a third planetary gear set 24 and a fourth planetary gear set 26. In certain exemplary embodiments, as shown in FIG. 1, third and fourth planetary gear sets 24, 26 may be a Simpson planetary gear set, e.g., such that third and fourth planetary gear sets 24, 26 share a joint sun gear or sun gears of third and fourth planetary gear sets 24, 26 are coupled or fixed together. The sun gear of second planetary gear set 22 may also constitute the ring gear of first planetary gear set 20, and planet gears of first and second planetary gear sets 20, 22 may be mounted to a joint planet carrier that is also coupled or fixedly connected to the ring gear of third planetary gear set 24. The planet carrier of third planetary gear set 24 may also be coupled or fixedly connected to the ring gear of fourth planetary gear set 26.

As may be seen in FIG. 1, automatic transmission 10 further includes a plurality of shifting elements. In particular, automatic transmission 10 includes a plurality of non-positive shift elements and at least one positive shifting element. The non-positive shift elements may be any suitable type of non-positive shift elements. For example, the non-positive shift elements may be multidisc friction shift elements or friction bands. In the exemplary embodiment of FIG. 1, the non-positive shifting elements includes a multidisc clutch B, a multidisc brake C, a multidisc brake D and a multidisc clutch E. The positive shifting elements may also be any suitable type of positive shifting elements, e.g., that provide a form fit or torque proof connection. For example, the positive shifting elements may be dog clutches, dog brakes or claw clutches. In the exemplary embodiment of FIG. 1, the at least one positive shifting element includes a dog clutch A and a dog clutch or brake F. As used herein, the term “clutch” may refer to mechanism for coupling or connecting two rotating components and the term “brake” may refer to a mechanism for coupling or connecting a rotating component to a non-rotating or static component.

The shifting elements of automatic transmission 10 selectively adjust between an open or disengaged configuration and a closed or engaged configuration. In the disengaged configuration, the shifting elements do not engage an associated component of the four planetary gear sets, e.g., and do not or negligibly interfere with rotation of the associated component of the four planetary gear sets relative to the shifting elements. Conversely, in the engaged configuration, the shifting elements engage the associated component of the four planetary gear sets, e.g., and hinder or prevent rotation of the associated component of the four planetary gear sets relative to the shifting elements. As may be seen in FIG. 1, dog clutch A selectively connects or couples input shaft 12 to the sun gear of second planetary gear set 22 and the ring gear of first planetary gear set 20. Multidisc clutch B selectively connects or couples input shaft 12 to the sun gear of first planetary gear set 20. Multidisc brake C selectively connects or couples a transmission housing 16 to the sun gear of first planetary gear set 20. Multidisc brake D selectively connects or couples transmission housing 16 to the ring gear of second planetary gear set 22. Multidisc clutch E selectively connects or couples input shaft 12 to the planet carrier of third planetary gear set 24 and the ring gear of fourth planetary gear set 26. Dog clutch F selectively connects or couples transmission housing 16 to the sun gear of third and fourth planetary gear sets 24, 26.

Automatic transmission 10 also includes an electronic control unit 28, an input speed sensor 30 and an output speed sensor 32. Electronic control unit 28 is in operative communication with various components of automatic transmission 10, including input speed sensor 30 and output speed sensor 32, to regulate operation of automatic transmission 10. Electronic control unit 28 may include a memory and microprocessor, such as a general or special purpose microprocessor operable to execute programming instructions or micro-control code associated with operating of automatic transmission 10. The memory may represent random access memory such as DRAM, or read only memory such as ROM or FLASH. Alternatively, electronic control unit 28 may be constructed without using a microprocessor, e.g., using a combination of discrete analog and/or digital logic circuitry (such as switches, amplifiers, integrators, comparators, flip-flops, AND gates, and the like) to perform control functionality instead of relying upon software.

Electronic control unit 28 may be mounted on an exterior of transmission housing 16. Electronic control unit 28 is in operative communication with solenoid valves of the shifting elements of automatic transmission 10. Thus, electronic control unit 28 may selectively adjust the shifting elements between the engaged configuration and the disengaged configuration, e.g., by selectively opening and closing the associated solenoid valves of the shifting elements. In such a manner, electronic control unit 28 may shift automatic transmission 10 between gears during operation of automatic transmission 10, e.g., based at least in part on signals from input speed sensor 30 and output speed sensor 32, as will be understood by those skilled in the art.

Input speed sensor 30 is configured for measuring a speed, e.g., rotations per minute (RPM), of input shaft 12. Input speed sensor 30 may be positioned adjacent input shaft 12 or a turbine of an associated torque coupling. Input speed sensor 30 may be any suitable type of sensor. For example, input speed sensor 30 may be a Hall effect sensor, an optical sensor, etc. Electronic control unit 28 may receive a signal from input speed sensor 30 corresponding to the speed of input shaft 12.

5

Output speed sensor **32** is configured for measuring a speed, e.g., rotations per minute (RPM), of output shaft **14**. Output speed sensor **32** may be positioned adjacent output shaft **14**. Output speed sensor **32** may be any suitable type of sensor. For example, output speed sensor **32** may be a Hall effect sensor, an optical sensor, etc. Electronic control unit **28** may receive a signal from output speed sensor **32** corresponding to the speed of output shaft **14**.

FIG. **2** illustrates a table **200** of an exemplary shifting scheme as may be used with automatic transmission **10**. As may be seen in FIG. **2**, automatic transmission **10** includes nine forward gears and one reverse gear. The forwards gears include: first gear “1”, second gear “2”, third gear “3”, fourth gear “4”, fifth gear “5”, sixth gear “6”, seventh gear “7”, eighth gear “8”, and ninth gear “9”. The reverse gear is labeled “R”. In table **200**, cells filled with “x” indicate the engaged configuration, and blank cells indicate the disengaged configuration. Thus, e.g., dog clutch A, multidisc brake D and dog clutch F are in the engaged configuration in first gear, and multidisc clutch B, multidisc brake C and multidisc clutch E are in the disengaged configuration in first gear. As another example, dog clutch A, multidisc brake C and dog clutch F are in the engaged configuration in second gear, and multidisc clutch B, multidisc brake D and multidisc clutch E are in the disengaged configuration in second gear. In the fourth gear, dog clutch A, multidisc clutch E and dog clutch F are in the engaged configuration. It should be understood that in certain exemplary embodiments, dog clutch A need not be in the engaged configuration to operate automatic transmission **10** in fourth gear. Thus, multidisc clutch E and dog clutch F may be the only shifting elements of automatic transmission **10** in the engaged configuration to operate automatic transmission **10** in fourth gear, in certain exemplary embodiments.

As discussed above, automatic transmission **10** includes nine forward gears and one reverse gear. Thus, automatic transmission **10** is generally referred to as a “nine-speed automatic transmission.” However, it should be understood that automatic transmission **10** is provided by way of example only and that the present subject matter may be used in or with any suitable automatic transmission. Thus, the present subject matter is not intended to be limited to use with automatic transmission **10**. As an example, the present subject matter may be used in automatic transmissions having five forward gears, six forward gears, eight forward gears, etc.

FIG. **3** illustrates a method **300** for operating an automatic transmission according to an exemplary embodiment of the present subject matter. Method **300** may be used in or with any suitable transmission. For example, method **300** may be used with automatic transmission **10** (FIG. **1**). The electronic control unit **28** of automatic transmission **10** may be programmed or configured to implement method **300**. Utilizing method **300**, a positive shifting element of automatic transmission **10**, such as dog clutch A or dog clutch F, may be synchronized and engaged, e.g., when an associated vehicle is stopped or operating at slow speeds. In particular, method **300** may be used to synchronize and engage dog clutch A when an associated vehicle is stopped on a sloped surface, such as a hill.

FIGS. **4** and **5** illustrate plots of shifting element actuation for automatic transmission **10** during method **300**. FIG. **4** provides a plot of shifting element actuation, including actuation of dog clutch A, with teeth of dog clutch A butting against one another during the actuation process. FIG. **5** provides a plot of shifting element actuation, including actuation of dog clutch A, with teeth of dog clutch A locking

6

against one another during the actuation process. Method **300** is described in greater detail below with reference to FIGS. **4** and **5**.

In FIGS. **4** and **5**, lines labeled “current of C”, “current of D” and “current of E” correspond to a command current supplied to a respective solenoid valve of multidisc brake C, multidisc brake D and multidisc clutch E. Electronic control unit **28** may selectively adjust the current supplied to the respective solenoid valve of multidisc brake C, multidisc brake D and multidisc clutch E as shown in FIGS. **4** and **5**. The line labeled “position of A” corresponds to a measured or detected position for dog clutch A, with the lower position corresponding to the disengaged configuration, the higher position corresponding to the engaged configuration, and the middle position corresponding to an intermediate position between the engaged and disengaged configurations. Dog clutch A may be in the intermediate position, e.g., when teeth of dog clutch A are butting against one another or when teeth of dog clutch A are locked together. The line labeled “line pressure” corresponds to a pressure supplied to shifting elements of automatic transmission **10**, such as dog clutch A, multidisc brake C, multidisc brake D and multidisc clutch E. Electronic control unit **28** may selectively increase the command line pressure as shown in FIGS. **4** and **5**, e.g., by selectively increasing an idle speed of a motor coupled to input shaft **12**. The line “input speed” corresponds to a measured or detected speed of input shaft **12**, e.g., from input speed sensor **30**, and the line “output speed” corresponds to a measured or detected speed of output shaft **14**, e.g., from output speed sensor **32**. In FIGS. **4** and **5**, the illustrated command current supplied to the respective solenoid valve of multidisc brake C, multidisc brake D and multidisc clutch E may also correspond or correlate to the fluid pressure supplied to such shifting elements.

At step **310**, a positive shifting element of automatic transmission **10**, such as dog clutch A, is synchronized in order to permit the positive shifting element to be engaged. Dog clutch F may engaged prior to starting method **300**, e.g., before step **310**. As an example, during step **310**, a friction shifting element of automatic transmission **10** may be closed. In particular, multidisc brake D may be closed at step **310**, as may be seen in FIGS. **4** and **5**. Electronic control unit **28** may open a solenoid valve of multidisc brake D in order to close multidisc brake D at step **310**. In particular, as may be seen in FIGS. **4** and **5**, electronic control unit **28** may first open the solenoid valve of multidisc brake D to a first position by pulsing the current supplied to multidisc brake D to a first level L1, e.g., in order to fill any void(s) within a line to multidisc brake D with fluid. Electronic control unit **28** may then decrease the current supplied to the solenoid valve of multidisc brake D and increase the current supplied to the solenoid valve of multidisc brake D along a first actuating trajectory T1 until the current supplied to the solenoid valve of multidisc brake D reaches an actuation value A1 and the multidisc brake D is in the actuated configuration. In such a manner, multidisc brake D may be closed at step **310** in order to assist with synchronizing dog clutch A.

In addition, a second friction shifting element of automatic transmission **10** may be brought to an engaged configuration of the second friction shifting element at step **310**. For example, multidisc clutch E may be brought to an engaged configuration of multidisc clutch E at step **310**, as may be seen in FIGS. **4** and **5**. Electronic control unit **28** may open a solenoid valve of multidisc clutch E in order to bring multidisc clutch E to its engaged configuration at step **310**. In particular, as may be seen in FIGS. **4** and **5**, electronic

control unit **28** may first open the solenoid valve of multidisc clutch E to a first position by pulsing the current supplied to multidisc clutch E to a second level L2, e.g., in order to fill any void(s) within a line to multidisc clutch E with fluid. Electronic control unit **28** may then decrease the current supplied to the solenoid valve of multidisc clutch E and increase the current supplied to the solenoid valve of multidisc clutch E along a second actuating trajectory T2 such that the multidisc clutch E is positioned at the engaged configuration of multidisc clutch E. In such a manner, multidisc clutch E may be brought to the engaged configuration of multidisc clutch E at step **310**. As may be seen in FIGS. **4** and **5**, multidisc clutch E may be brought to the engaged configuration of multidisc clutch E after beginning to close multidisc brake D to the actuated configuration during step **310**.

Step **310** may assist with reducing a speed differential between rotating components of the positive shifting element of automatic transmission **10**. For example, step **310** may assist with reducing a speed differential between rotating components of dog clutch A. Thus, step **310** may assist with synchronizing dog clutch A in order to assist with actuating dog clutch A from the disengaged configuration to the engaged configuration. In particular, by closing multidisc brake D and bringing multidisc clutch E to its engaged configuration, dog clutch A may be synchronized and actuated to the engaged configuration.

At step **310**, automatic transmission **10** may also be operated such that an output speed of automatic transmission **10** is less than a threshold output speed. As an example, electronic control unit **28** may receive speed measurements of output shaft **14** from output speed sensor **32** to measure the output speed of automatic transmission **10** at step **310**. The threshold output speed may be any suitable speed. For example, the threshold output speed may be zero rotations per minute, no greater than one thousand rotations per minute, no greater than five hundred rotations per minute, etc. Thus, a vehicle associated with automatic transmission **10** may be stopped or moving slowly at step **310**.

At step **320**, automatic transmission **10**, e.g., and an associated vehicle, are braked with a friction shifting element of automatic transmission **10**. For example, a third friction shifting element of automatic transmission **10** may be closed at step **320**. In particular, multidisc brake C may be closed at step **320**, as may be seen in FIGS. **4** and **5**. Electronic control unit **28** may open a solenoid valve of multidisc brake C in order to close multidisc brake C at step **320**. In particular, as may be seen in FIGS. **4** and **5**, electronic control unit **28** may first open the solenoid valve of multidisc brake C to a first position by pulsing the current supplied to multidisc brake C to a third level L3, e.g., in order to fill any void(s) within a line to multidisc brake C with fluid. Electronic control unit **28** may then decrease the current supplied to the solenoid valve of multidisc brake C and increase the current supplied to the solenoid valve of multidisc brake C along a third actuating trajectory T3 in order to adjust the multidisc brake C to the actuated configuration. In such a manner, multidisc brake C may be closed at step **320** in order to assist with braking automatic transmission **10** and/or a vehicle associated with automatic transmission **10**.

By braking automatic transmission **10** and/or the vehicle associated with automatic transmission **10** at step **320**, a vehicle associated with automatic transmission **10** may be hindered or prevented from rolling backwards. Thus, while on a hill or other sloped surface, multidisc brake C may brake automatic transmission **10** and/or the vehicle associ-

ated with automatic transmission **10** at step **320**. In such a manner, multidisc brake C may limit or prevent damage to a positive shifting element of automatic transmission **10**, e.g., while the positive shifting element of automatic transmission **10** is shifted to the engaged configuration.

At step **330**, a positive shifting element of automatic transmission **10** is commanded to close or actuate to the engaged configuration. As an example, dog clutch A may be commanded to actuate to from the disengaged configuration to the engaged configuration at step **330**, e.g., after dog clutch A is synchronized during step **310**. In particular, electronic control unit **28** may open a solenoid valve of dog clutch A such that a pressure of fluid supplied to dog clutch A is increased in order to command dog clutch A to adjust to the engaged configuration at step **330**, as shown in FIGS. **4** and **5**.

At step **340**, a position of the positive shifting element of automatic transmission **10** is determined or established. Electronic control unit **28** may determine the position of dog clutch A at step **340**. Any suitable method or mechanism may be used to determine or establish that position of dog clutch A at step **340**. As an example, electronic control unit **28** may utilize the method described in U.S. Pat. No. 8,812,200 of Novak, which is hereby incorporated by reference for all purposes, to determine the position of dog clutch A at step **340**. As another example, electronic control unit **28** may utilize a pressure difference across an actuating piston of the dog clutch A to determine the position of the position of dog clutch A at step **340**, as will be understood by those skilled in the art.

If the position of the positive shifting element is in an intermediate position at step **340**, a pressure of fluid supplied to a non-positive shifting element of automatic transmission **10** is increased at step **350**. For example, a pressure of fluid supplied to multidisc brake D may be increased at step **350**, as may be seen in FIGS. **4** and **5**. Electronic control unit **28** may open a solenoid valve of multidisc brake D in order to increase the pressure of fluid supplied to brake D at step **350**. In particular, as may be seen in FIGS. **4** and **5**, electronic control unit **28** may further open the solenoid valve of multidisc brake D to a second position by increasing the current supplied to multidisc brake D to a third actuation value A3 along a fourth actuating trajectory T4 in order to increase the pressure of fluid supplied to multidisc brake D at step **350**. Multidisc brake C may continue brake automatic transmission **10** and/or the vehicle associated with automatic transmission **10** during step **350**. As may be seen in FIGS. **4** and **5**, multidisc clutch E may also be opened at step **350**, e.g., by opening decreasing the current supplied to the solenoid valve of multidisc clutch E along the fifth actuating trajectory T5.

During step **350**, a rotational speed differential between torque couplings of dog clutch A may continue to increase. Thus, if teeth of dog clutch A are butting against one another and dog clutch A is stuck in the intermediate position, the rotational speed differential between torque couplings of dog clutch A may be increased at step **350** in order to eliminate the tooth butt condition of dog clutch A. As shown in FIG. **4**, dog clutch A may be actuated from the intermediate position to the engaged configuration when the tooth butt condition of dog clutch A is eliminated at step **350**. With dog clutch A synchronized and in the engaged configuration, multidisc brake C, multidisc brake D and multidisc clutch E may be opened to the disengaged configuration at step **380**, as shown in FIGS. **4** and **5**.

If the position of the positive shifting element is in not the intermediate position at step **340**, dog clutch A is in the

engaged configuration. Thus, multidisc brake C, multidisc brake D and multidisc clutch E may be opened at step 380, e.g., by reducing current supplied to solenoid valves of multidisc brake C, multidisc brake D and multidisc clutch E. In addition, automatic transmission 10 may be shifted to first gear or the reverse gear with dog clutch A in the engaged configuration after step 380.

At step 360, the position of the positive shifting element of automatic transmission 10 is again determined or established. If the position of the positive shifting element is still the intermediate position, a pressure of fluid supplied to a non-positive shifting element of automatic transmission 10 may be pulsed at step 370. For example, a pressure of fluid supplied to multidisc brake D may be pulsed at step 370, as may be seen in FIG. 5. Electronic control unit 28 may successively open and close a solenoid valve of multidisc brake D in order to pulse the pressure of fluid supplied to brake D at step 370. If increasing the pressure of fluid supplied to multidisc brake D at step 350 does not permit or result in dog clutch A shifting to the engaged configuration, teeth of dog clutch A may be sticking. By pulsing the pressure of fluid supplied to multidisc brake D, the sticking may be overcome and dog clutch A may shift to the engaged configuration. In such a manner, spline lock condition of dog clutch A may be eliminated or overcome. The pressure of fluid supplied to the non-positive shifting element of automatic transmission 10 may be pulsed any suitable numbers of times at step 370. For example, the non-positive shifting element of automatic transmission 10 may be pulsed once, two times, three times, four times, five times, or more.

As may be seen in FIG. 5, multidisc clutch E may also be closed at step 370, e.g., in order to assist with overcoming the spline lock condition of dog clutch A. In particular, electronic control unit 28 may open the solenoid valve of multidisc clutch E by increasing the current supplied to the solenoid valve of multidisc clutch E to a fourth level A4. Multidisc brake C may also stop braking automatic transmission 10 and/or the vehicle associated with automatic transmission 10 during step 370.

It should be understood that while described in the context of automatic transmission 10, method 300 may be used to synchronize and engage a positive shifting element in any suitable transmission. In addition, while described in the context of synchronizing and engaging dog clutch A, method 300 may be used to detect synchronize and engage dog clutch A of automatic transmission 10, in alternative exemplary embodiments.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method for operating an automatic transmission, the automatic transmission having a plurality of non-positive shifting elements and at least one positive shifting element, the method comprising:

synchronizing a first positive shifting element of the at least one positive shifting element;

braking the automatic transmission with a first non-positive shifting element of the plurality of non-positive shifting elements;

commanding the first positive shifting element of the at least one positive shifting element to actuate from a disengaged configuration to an engaged configuration after said step of synchronizing, a second non-positive shifting element and a third non-positive shifting element of the plurality of non-positive shifting elements being in the engaged configuration at said step of commanding;

establishing a position of the first positive shifting element of the at least one positive shifting element after said step of commanding; and

increasing a pressure of fluid supplied to the second non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is an intermediate position at said step of establishing.

2. The method of claim 1, further comprising decreasing a pressure of fluid supplied to the third non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is the intermediate position at said step of establishing.

3. The method of claim 1, further comprising determining the position of the first positive shifting element of the at least one positive shifting element after said step of increasing and pulsing the pressure of fluid supplied to the second non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is the intermediate position at said step of determining.

4. The method of claim 3, further comprising opening the third non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is the intermediate position at said step of establishing and closing the third non-positive shifting element of the plurality of non-positive shifting elements if the position of the first positive shifting element of the at least one positive shifting element is the intermediate position at said step of determining.

5. The method of claim 4, wherein the position of the first positive shifting element of the at least one positive shifting element is an engaged position after said steps of pulsing and closing.

6. The method of claim 3, further comprising adjusting the first non-positive shifting element of the plurality of non-positive shifting elements to a disengaged configuration during said step of pulsing.

7. The method of claim 3, wherein said step of pulsing comprises sequentially reducing and boosting the pressure of fluid supplied to the second non-positive shifting element of the plurality of non-positive shifting elements at least three times.

8. The method of claim 1, wherein a second positive shifting element of the at least one positive shifting element is in an engaged position at said step of commanding.

9. The method of claim 1, wherein increasing a line pressure of the automatic transmission comprises increasing an idle speed of a motor a vehicle associated with the automatic transmission during said step of synchronizing.

11

10. The method of claim 1, wherein a vehicle associated with the automatic transmission does not roll backwards during said steps of synchronizing, braking, commanding, establishing and increasing.

11. A method for operating a nine-speed automatic transmission, the nine-speed automatic transmission including a dog clutch A, a friction shifting element C, a friction shifting element D, and a friction shifting element E, the method comprising:

synchronizing the dog clutch A;

braking the automatic transmission with the friction shifting element C;

commanding the dog clutch A to actuate from a disengaged configuration to an engaged configuration after said step of synchronizing, the friction shifting element D and the friction shifting element E being in the engaged configuration at said step of commanding; establishing a position of the dog clutch A after said step of commanding; and

increasing a pressure of fluid supplied to the friction shifting element D if the position of the dog clutch A is an intermediate position at said step of establishing.

12. The method of claim 11, further comprising decreasing a pressure of fluid supplied to the friction shifting element E if the position of the dog clutch A is the intermediate position at said step of establishing.

13. The method of claim 11, further comprising determining the position of the first positive shifting element of the at least one positive shifting element after said step of increasing and pulsing the pressure of fluid supplied to the

12

friction shifting element D if the position of the dog clutch A is the intermediate position at said step of determining.

14. The method of claim 13, further comprising opening the friction shifting element E if the position of the dog clutch A is the intermediate position at said step of establishing and closing the friction shifting element E if the position of the dog clutch A is the intermediate position at said step of determining.

15. The method of claim 14, wherein the position of the dog clutch A is an engaged position after said steps of pulsing and closing.

16. The method of claim 13, further comprising adjusting the friction shifting element C to a disengaged configuration during said step of pulsing.

17. The method of claim 13, wherein said step of pulsing comprises sequentially reducing and boosting the pressure of fluid supplied to the friction shifting element D at least three times.

18. The method of claim 11, wherein a dog clutch F of the automatic transmission is in an engaged position at said step of commanding.

19. The method of claim 11, wherein increasing a line pressure of the automatic transmission comprises increasing an idle speed of a motor a vehicle associated with the automatic transmission during said step of synchronizing.

20. The method of claim 11, wherein a vehicle associated with the automatic transmission does not roll backwards during said steps of synchronizing, braking, commanding, establishing and increasing.

* * * * *